International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 05, May-2019

Establishing a Relationship between Half Cell Potential Metre and Impact Echo for Corrosion Assessment

P. S. Lande[1], P.S. Borkar[2],

[1]*Department of applied mechanics GCOEA,*
[2]*Department of applied mechanics GCOEA,*

Abstract*— The corrosion damage of any reinforced concrete structure is a severe and invisible injury. The corrosion damage can be detected by any electrochemical methods but these methods do not give any perception about the condition of the structure. Therefore in this paper, we had tried to understand the impact echo (IE) responses for non-corroded and corroded rebar (reinforcing steel bar) and established a relationship between impact echo and half cell potential meter. The main objective of this paper is to study the practicability, reliability, and applicability of detecting the rebar corrosion in the concrete block by using the impact-echo method associated with half cell potential meter. For this purpose, we had cast six beams and used an electrolysis process for corrosion of rebar.

***Keywords*— corrosion, acceleration, rebar, concrete, amplitude.**

I. Introduction

In reinforced concrete structure rebar corrosion is an important problem which may lead to severe damage. The corrosion of rebar generally causes a decrease in adhesion between the rebar and the concrete, volume changes (shrinkage, creep) unfavourably affecting concrete. Lastly, the decrease in rebar cross section influences the load bearing capacity of a structure. Rebar corrosion which is not characterized by the covering layer destruction is especially dangerous. This type of corrosion is not due to the concrete being attacked by an environment, but rather, the change in the chemical property of the concrete and it attacked the rebar. The occurrence of corrosion cannot be seen from the exterior surface of a structure, therefore studies of non-destructive method allow the researchers to detect the degree of corrosion from built-in rebars are given so much attention.

At present corrosion, evaluation of steel in concrete is done by both the corrosion rate and corrosion potential using electrochemical methods such as the open circuit potential (OCP) method, direct current (DC) polarization method and alternating (AC) impedance method. However, these electrochemical methods do not give any indication about the state of failure of reinforced concrete (RC) structures. As non-destructive testing broadly used in civil engineering, for the detection of both the physical properties and internal and external state of RC structure, Though the result obtained from non-destructive technique can only provide a qualitative description for RC structure. Every aspect of corrosion evaluation can be taken into account If the results taken from the impact-echo test are correlated with electrochemical methods.

For flaws detection in concrete Carnio and Sansalone [1] developed an impact-echo method. This method is based on the concept of transient stress wave propagation. [2] They carried out an experiment on the specimens cast in the laboratory that contain artificial flaws, (honeycombing, cracks, and underground ducts) at the known locations and obtained a frequency domain for determining their location. [3] They used the IE method for the detection of concrete with or without asphalt overlays. The finite element method and IE method to illustrate the impact of different aspects such as rebar diameter, depth, impact duration, and impact echo test configuration is used by Cheng and Sansalone [4] they also [5] used ie method for identifying delamination in concrete plate-like structure such as bridge decks, slabs, and walls. [6] M. Liang and P. Su established a relation between impact echo and electrochemical methods for corrosion detection.

According to Andrade & Alonso [7] and Assouli [8], the OCP and electrical resistivity are the most commonly used methods for evaluating the corrosion of reinforcements, even if they are solely qualitative techniques evaluating the thermodynamics of the process, not providing data about the kinetics of the phenomenon. Despite this being declared old. The half cell potential method is one of the more common electrochemical method used for examination, monitoring and diagnostic of the corrosion of the RC structure. Lima [9], being indicated as a method of monitoring in inspection works in the field as recorded in the following studies: Andrade & Alonso [7]; Liam [9]; Helene [10]; Broomfield [11]; Elsener [12]; Feliu [13]; Helene, They showed that the half cell potential measurements can be affected by factors such as water-cement ratio, moisture content, concrete cover thickness and rate of chloride contamination.

II. Theoretical Background

A. Impact Echo Method

IE method is also known as the acoustic method this method is based on a principal of stress wave propagation (P and S wave). IE method is also known as the acoustic method which is based on the principle of stress wave propagation. The test head of IE includes the automated solenoid impactor which provides the impact to the surface of the specimen to be tested and displacement transducer which receives the reflected waves from the surface of a specimen and shows the result (graph in) time domain, and the final results are obtained in the form of a frequency domain using WinIE software.

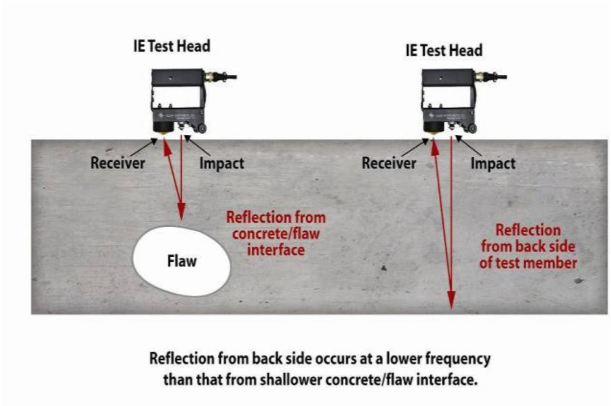


Fig. 1 shows the working of IE the stress wave reflects from the surface of flaws of the concrete

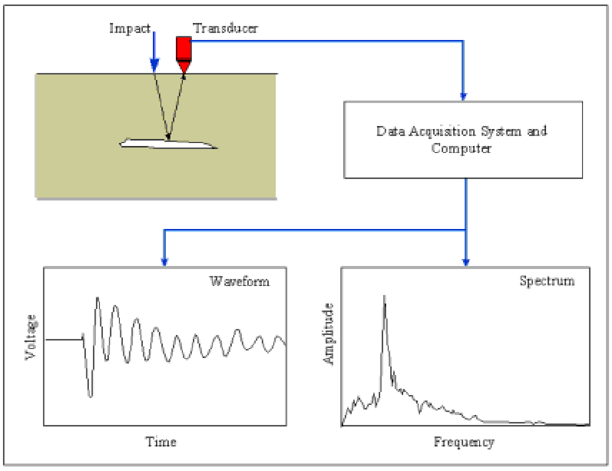


Fig. 2 schematic diagram of working of IE

The IE method [1] involves the initiation of transient stress waves into the test specimen by mechanical impact and observing the surface displacement induced by the arrival of reflections of these waves from external boundaries and internal defects. the displacement recorded in the waveform is analyzed in the frequency domain. The distance of defect or interface can be determined by measuring the travel time from the start of the wave to the reception of the reflection of this wave. Let C_p P wave velocity in concrete beam or plate and T is the thickness of detecting or interface from the surface. ꝱt is the travel time between the successive arrivals of p wave reflection from the bottom of the surface of a plate is given by eq.(1)

$$ꝱt = \frac{2T}{C_p} \qquad (1)$$

The corresponding frequency, *f*, of stress wave reflection is

$$f = \frac{1}{ꝱt} = \frac{C_p}{2T} \qquad (2)$$

When the underlying materials are acoustically stiffer (has large acoustic impedance) such as the interface of steel and concrete then the amount of deflection is also decided by the difference between the acoustic impedance of two materials. In such cases, eq(2) is no longer valid. For such circumtances, eq. of frequency of reflection from the acoustic stiffer interface f_s to the depth of interface T_s is given by;

$$f_s = \frac{C_p}{4T_s} \qquad (3)$$

when the value of D/T_s is less than 0.3 the peak value from steel reflection in the spectrum will disappear or decrease. After the observations and many numerical results [4] given the equation to relate the dominant or central frequency of bar diameter and depth. Eq (3) is modified by multiplying by a factor ξ as follows:

$$f_s = \frac{\xi C_p}{4T_s} \qquad (4)$$

where ξ is defined by the empirical relationship as follows:

$$\xi = -0.6\frac{D}{T_s} + 1.5 \qquad (5)$$

This relationship is only valid for the bars with D/Ts less than 1 and greater than 0.3. these above-mentioned formulas are only used to identify defects in plate-like structures. If these formulas are used to predicts the flaws in the beam or column then the analysis of the frequency spectrum becomes very difficult this is proven by lin and Sansalone [19].

B. Half Cell Potential Meter:

The method of half-cell potential is based on a principal of potential difference between the half cell and reinforcing bar. the danger of corrosion of the reinforcement in the immediate region of the test location may be correlated empirically to the measured potential difference and The concrete functions as an electrolyte. fig 3 shows The half cell potential meter circuit. The results can be obtained in the form of a contour map or cumulative frequency diagram. Table 1 shows the risk of corrosion against the potential difference readings[20].

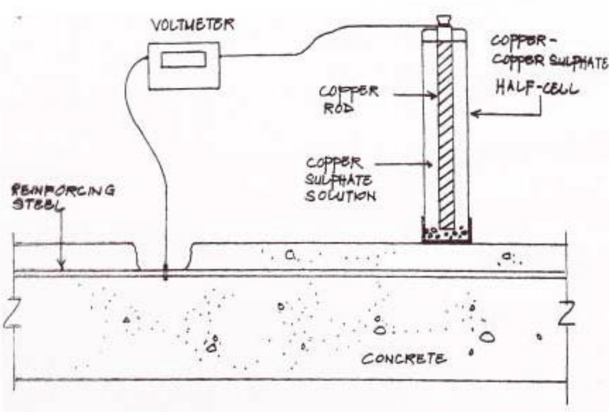


Fig. 3 working of HCP

TABLE I

RANGES OF CORROSION POTENTIAL AND THEIR CORELATION WITH PROBABILITY ACCORDING TO ASTM C 876

Potential Difference Level (mV)	**Chance of Re-bar Being Corroded**
less than -500	visible evidence of corrosion
-350 to -500	95%
-200 to -350	50%
More than -200	5%

III. EXPERIMENTAL METHOD

The bar used in this experiment is Fe 415 (#6 rebars with 16 mm diameter). The concrete mixture is as shown in table 2. 6 blocks of size 300*100*100 mm was prepared with steel bar embedded at the center as shown in fig 4, the electric wires are connected to the rebars to accelerate the corrosion damage. after demolding blocks are cured for 28 days.

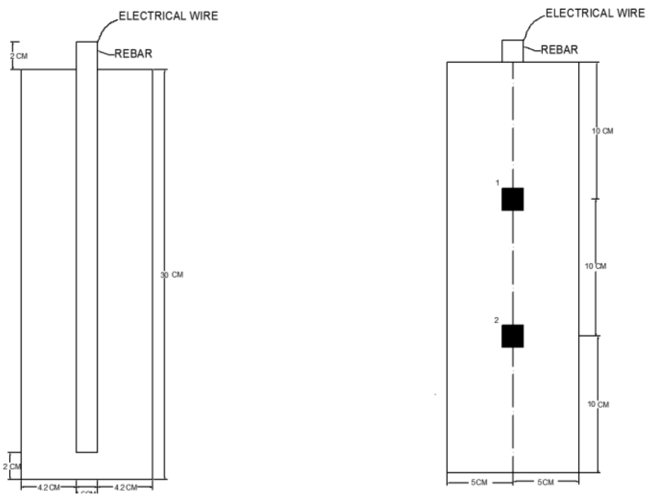


Fig. 4 Specimen size and rebar position

Before performing the IE test one first mark the position of impact source and receiver, here the positions are marked at 10cm intervals and readings are taken on all the four phases of a block. to accelerate the corrosion process the blocks were immersed in a 3.5% NaCl solution and connected to a DC power supply as shown in Fig. 5. The rebar was prepared as an anode and titanium alloy mesh as a cathode. The constant current density, 1 mA/cm2, was supplied. The supplied current was cut off once in every 24 hr, and the blocks were removed from the tanks, and half cell potential and IE testing were conducted.

The experimental procedures are described in detail as follows:

(a) Mark impact test number on the surface of RC blocks and then put it into the water until saturation.

(b) Execute the IE and half cell potential test when the RC blocks have dried at room temperature.

(c) Wrap the blocks into a titanium alloy sheet and put the RC blocks into the NaCl solution.

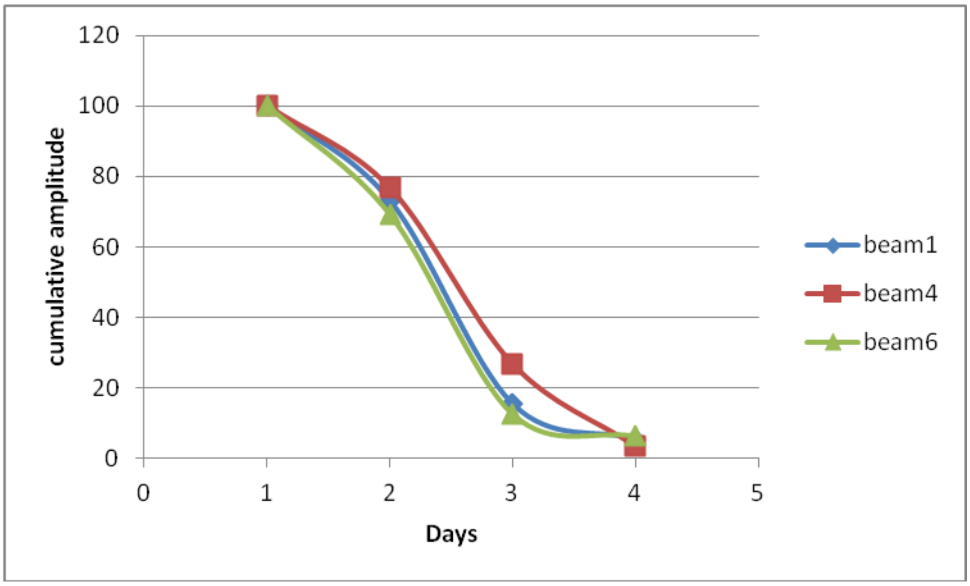
(d) after every 24 hr turn off the electric supply after accelerating corrosion. for accomplishing the ion stability the RC blocks were left untreated for an hour.

Repeat the procedure (b), (c),(d) until the specimen crack. After the data received from the IE test, one can get a frequency spectrum from a personal computer by the fast Fourier transform and then carries out the analysis.

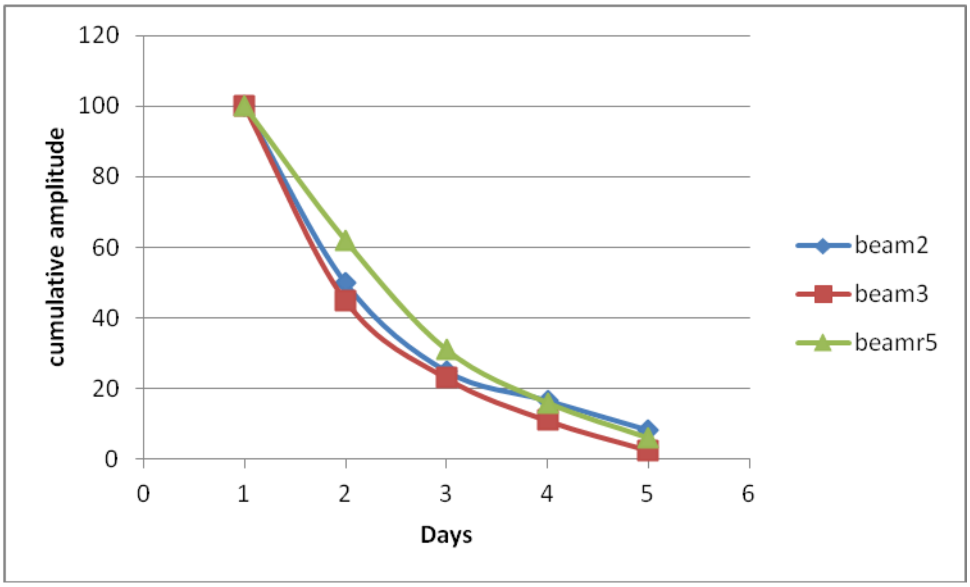
Fig.5 Accelerated corrosion assembly

IV. RESULTS

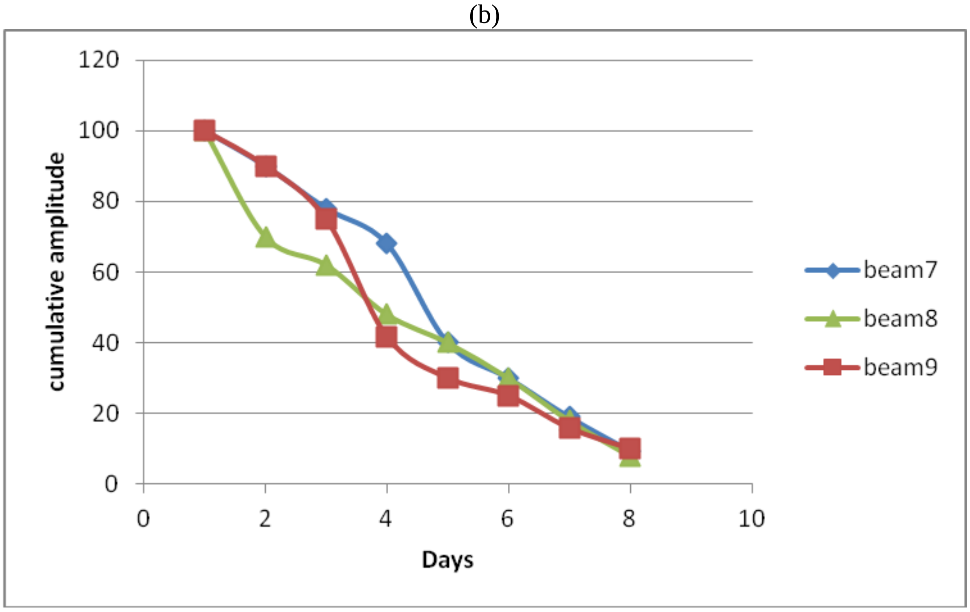
9 specimen were tested current is supplied in series 3 specimen were cracked after 3 days, another 3 specimen were cracked after 5 days and last 3 specimen were cracked after 8 days. 1st 6 specimens where supplied with 0.8mA current and last 3 specimen were supplied with 0.4 current. So that intermediate points can be found out. Graph 1a, b, c shows the days and cumulative amplitude decrease of the 9 specimen. Graphs shows that as corrosion increases there is decrease in amplitude.



(a)



(b)



(c)

Fig 5. Days Vs cumulative decrease in amplitude;(a) beam cracked in 4 days, (b) beam cracked in 5 days (c) beam cracked in 8 days

Fig 6. Cracked beam specimen

The thickness of the specimen is 100mm fig 7 shows the graph obtain from WinIR software as per eq. 2 the frequency at which total depth is located is 18.887 and we can clearly see that calculated frequency shows the nearly same depth hence concrete is sound. Fig 8 shows the decrease in amplitude at a frequency calculated by eq. 4 the Cp is taken as 3657.6m/sec and in fig 7 and 9 we can clearly shows the pattern of the graph between frequency 27.68 to 30KHz where bar is located, it can be identified by two similar amplitude frequency are separated by a small hump. Fig 8 shows the established linear relation between cumulative amplitude and HCP reading.

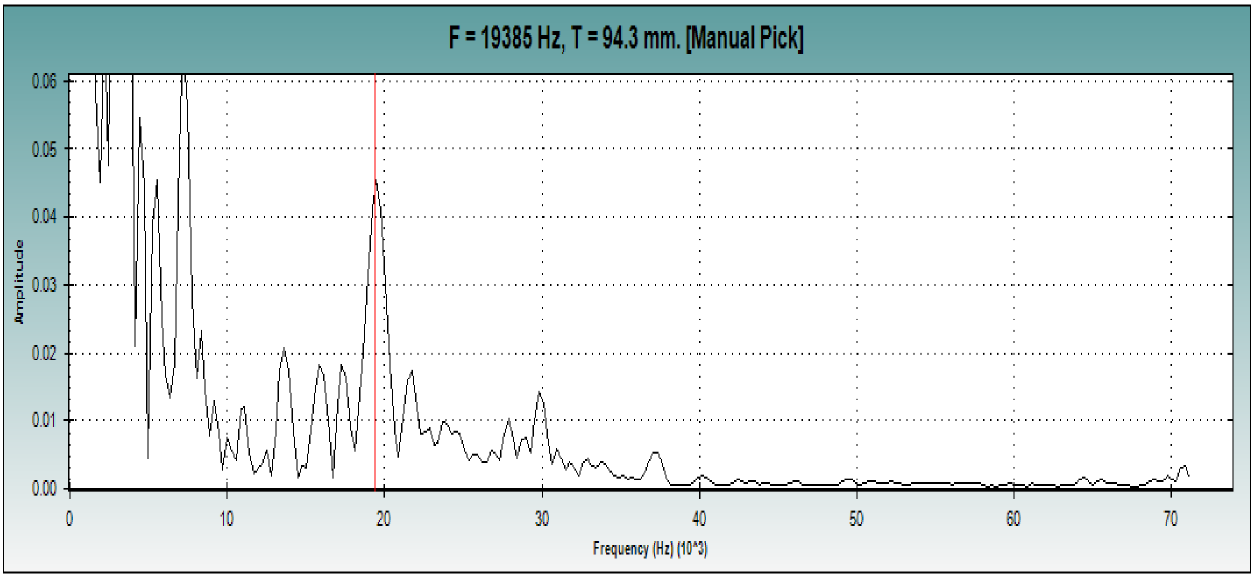


Fig. 7 Graph of reading no adil194.nde

TABLE II
READINGS OF BEAM 1 POINT C

Sr. No.	Days	amplitude	cumulative amplitude	HCP (mV)
adil193.nde	1	0.01	100	-45
adil369.nde	2	0.0074	74	-170
adil421.nde	3	0.00163	16.3	-385
adil517.nde	4	0.00062	6.2	-465

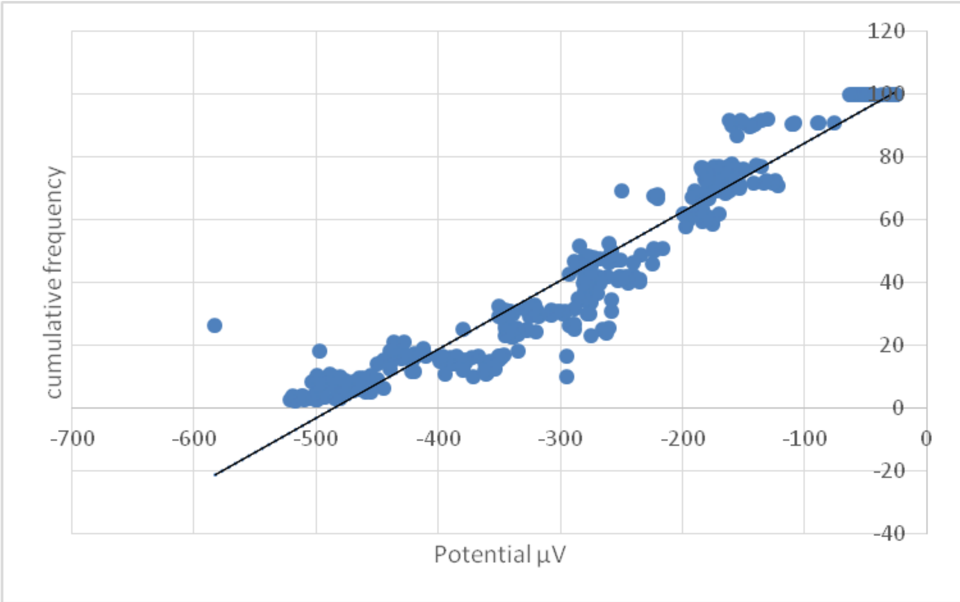
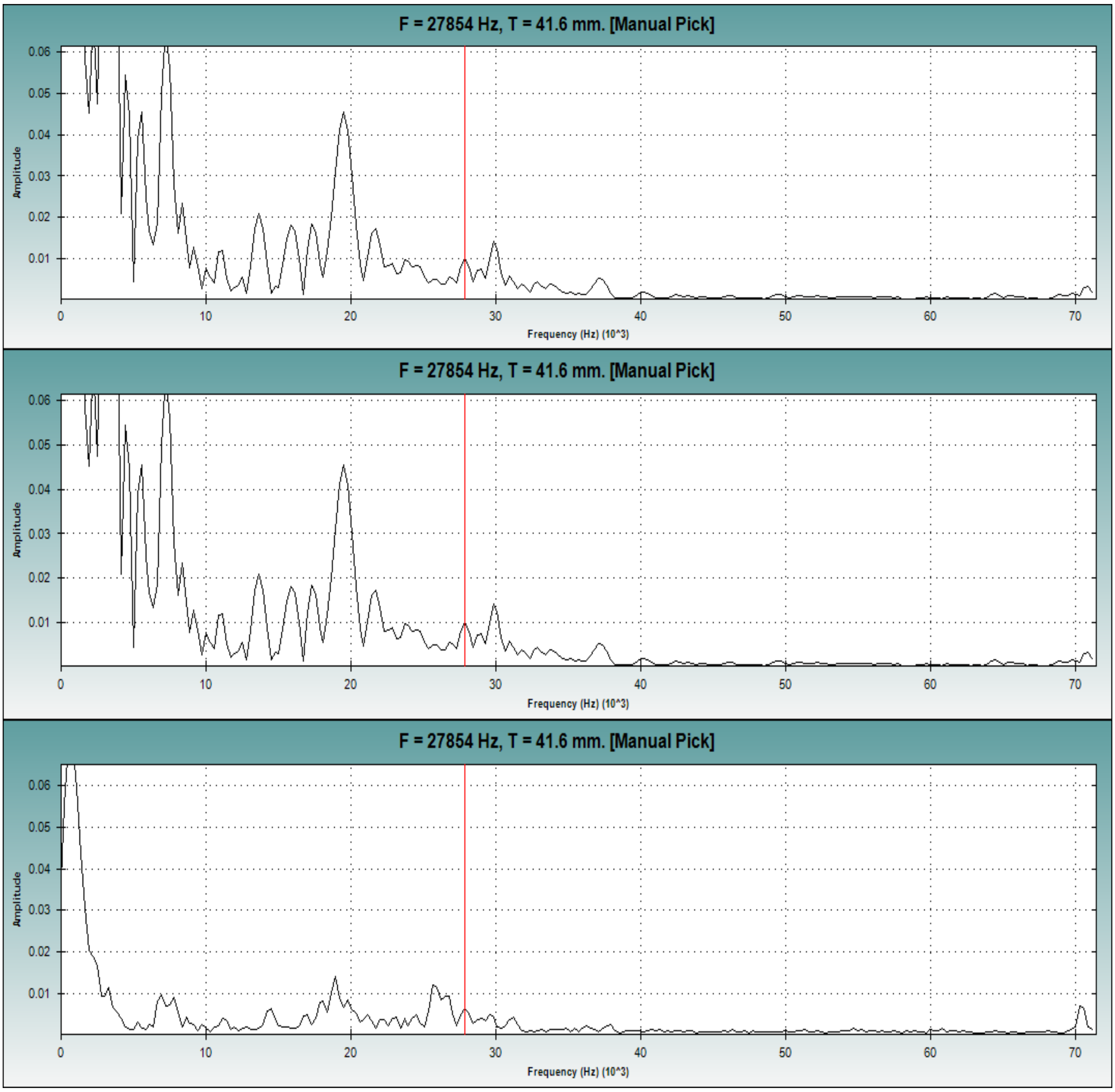


Fig. 8 Relationship between relative amplitude and HCP



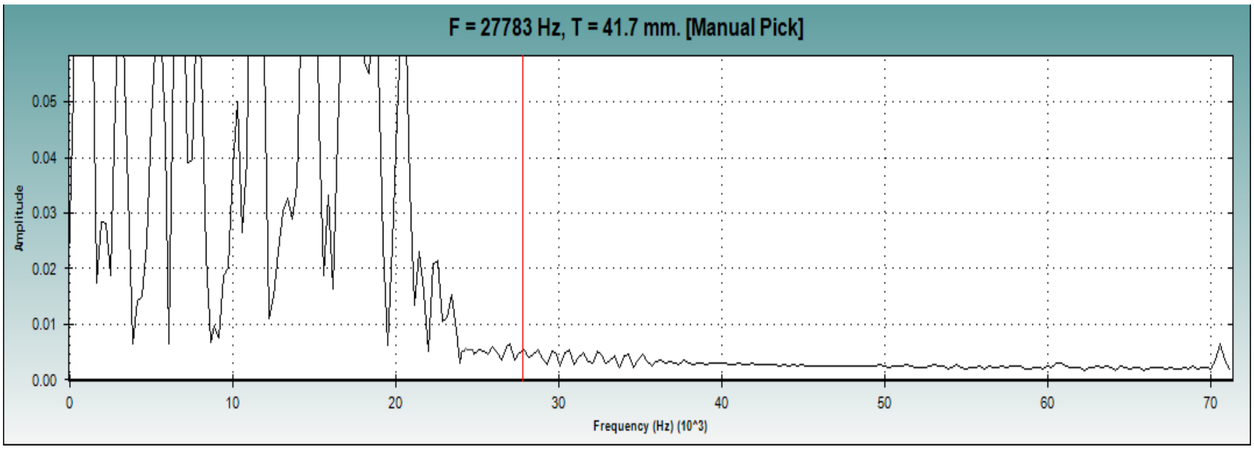


Fig. 9 Readings of table 2 showing decrease in amplitude

V. CONCLUSIONS

From the above study we have found the relationship between relative amplitude of IE and HCP readings. We also found that there is no significant change in the graph pattern as corrosion increase its only shows the decease in amplitude of the frequency. The pattern of graph where bar is located is identified.

As research can only show the intensity of corrosion which is a probability not a accurate corrosion rate one can establish a relation between the rate of corrosion and impact echo result

REFERENCES.

[1] N. Carino, M. Sansalone, N.N. Hsu, *Flaw detection in concrete by frequency spectrum analysis of impact-echo waveforms*, vol. 12, Int. Adv. Nondestr. Test., Gordon & Breach Science, 1986, pp. 117–146

[2] M. Sansalone, N.J. Carino, *Impact-echo method*, Concr. Int. 10 (4) (1988) 38–46.

[3] M. Sansalone, N.J. Carino, *Detecting delaminations in concrete slabs with and without overlays using the impact-echo method*, ACI Mater. J. 86 (2) (1989) 175– 184

[4] C.C. Cheng, M. Sansalone, *Effect on impact-echo signals caused by steel reinforcing bars and voids around bars*, ACI Mater. J. 90 (5) (1993) 421– 434.

[5] C. Cheng, M. Sansalone, *The impact-echo response of concrete plate containing delaminations*: Numerical, experimental and field studies, Mater. Struct. 26 (1993) 274– 285.

[6] Ming-Te Liang and Po-Jen SU, *Detection of corrosion damage of rebar in concrete using impact echo method*: cement and concrete research 31 (2001) 1427-14 1427-1436

[7] Assouli, B.; Ballivy, G.; Rivard, P. *Influence of environmental parameters on application of standard ASTM C876-91*: half cell potential measurements. Corrosion Engineering, Science and Technology, v.43, n.1, 2008, p. 93-96.

[8] Medeiros-Junior, R.A.; Lima, M.G. *Electrical resistivity of unsaturated concrete using different types of cement. Construction and Building Materials*, v.107, 2016, p.11-16.

[9] Liam, K.C.; Roy, S.K.; Wood, D.O.N. *Chloride ingress measurements and corrosion potential mapping study of a 24-year-old reinforced concrete jetty structure in a tropical marine environment*. Magazine of Concrete Research, v.44, n.160, 1992, p.205-215

[10] Broomfield, J.P.; Davies, K.; Hladky, K. *The use of permanent corrosion monitoring in new and existing reinforced concrete structure*s. Cement and Concrete Composites, v.24, n.1, 2002, p.27-34.

[11] Elsener, B.; Andrade, C.; Gulikers, J.; Polder, R.;Raupach, M. *Half-cell potential measurements – Potential mapping on reinforced concrete structure*s. Materials and Structures, v.36, 2003, p. 461-471.

[12] Feliu, S.; González, J.A.; Miranda, J.M.; Feliu, V. *Possibilities and problems of in situ techniques for measuring steel corrosion rates in large reinforced concrete structures*. Corrosion Science, v.47, n.1, 2005, p.217-238.

[13] Helene, P.; Pereira, F.; Castro, P. *Performance of a 40-Year-Old Concrete Bridge with Embedded, Prestressed Galvanized Strands*. Materials Performance, v.43, n.10, 2006, p.42-45.

